(51) International Patent Classification [6] : C03B 19/14, 19/06	A1	(11) International Publication Number: WO 98/27018
		(43) International Publication Date: 25 June 1998 (25.06.98)

(21) International Application Number: PCT/US97/20433

(22) International Filing Date: 7 November 1997 (07.11.97)

(30) Priority Data:
60/032,904   16 December 1996 (16.12.96)   US

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(81) Designated States: AU, BR, CA, CN, JP, KR, MX, RU, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: ORGANOMETALLICS FOR LIGHTWAVE OPTICAL CIRCUIT APPLICATIONS
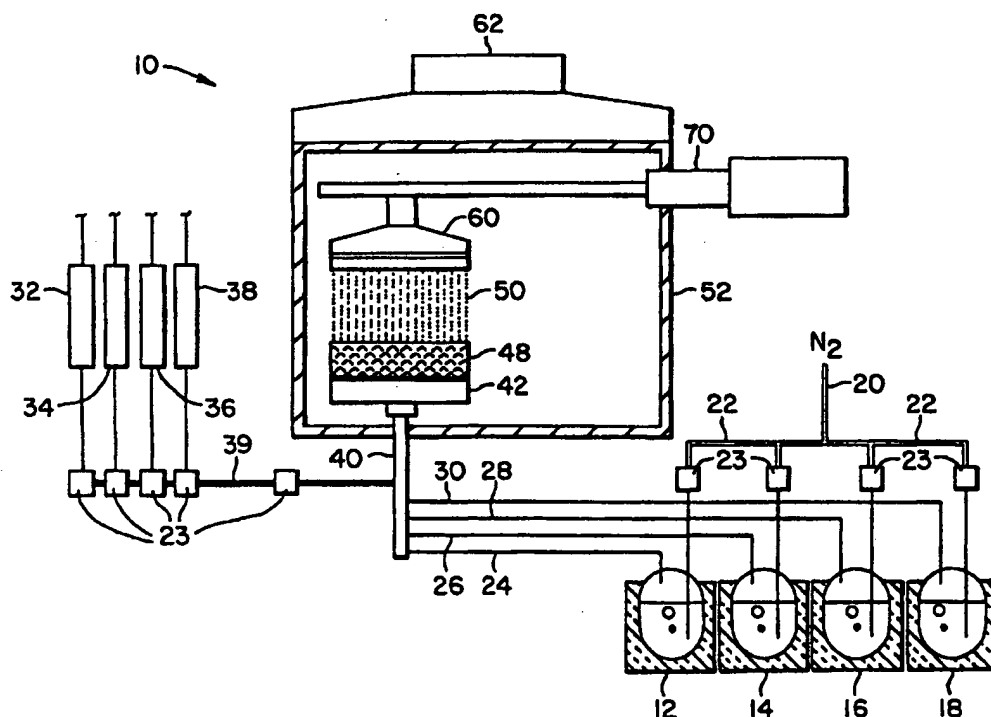
(57) Abstract

A plurality of organometallic compounds (12–18) are converted into vapors and are mixed along with combustion gases (32–38) to form a vapor stream that flows along through pipe (40). This vapor stream burns at burner (42) to form soot (50). This soot (50) deposits onto rotating substrate (60) so as to form a consolidated oxide layer.

ORGANOMETALLICS FOR LIGHTWAVE
OPTICAL CIRCUIT APPLICATIONS

5   FIELD OF THE INVENTION

This invention relates generally to conversion systems such as flame hydrolysis, and to the use of organometallic sources for depositing thin uniform oxide soot or pre-sintered glass layers on planar substrates. The deposited soot is consolidated into glass
10   layers. The glass layers form the core and cladding glasses that make up the optical waveguides in integrated optical circuits.

BACKGROUND OF THE INVENTION

15   Applicants have developed flame hydrolysis systems which deposit thin oxide soot layers on planar surfaces for Lightwave Optical Circuits (LOC) applications and the making of integrated optical waveguide devices such as integrated optical circuits. These soot layers are consolidated into glass layers which form optical waveguide cores and cladding.

20   U.S. Patent Application No. 08/581,186 filed 12/29/95, Bandwidth-Adjusted Wavelength Demultiplexer, by Denis M. Trouchet, discloses such an optical circuit which functions as a wavelength demultiplexer.

Conventional methods have relied on the combustion of halide compounds which are advantageous for certain applications, but which also have serious drawbacks. Halogens such as chlorine will strip some of the oxides from the source material which will result in nonuniformity in the glass composition resulting from the deposited soot

5   layer. This nonuniformity translates into a degradation of the optical properties of the resulting waveguiding glass layers made by these conventional halide processes

In addition to the above, the end product of the combustion reaction of the halides is chlorine, which can react with moisture in the air to form HCl, which is highly corrosive and toxic and requires equipment capable of containing it.

10   It can therefore be seen that there is a need for a system for forming oxide soot layers on planar surfaces or substrates which provides for improved uniformity in the glass composition, better optical performance of waveguiding glass layers formed by the flame hydrolysis technique, and an elimination of toxic or harmful combustion by-products.

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SUMMARY OF THE INVENTION

The invention is directed to the use of organometallic sources for passive planar waveguide applications and making integrated optical waveguide devices such as

20   integrated optical circuits. The advantages of using these materials is the elimination of chlorine from the system. Chlorine will strip some of the laydown oxides from these source materials via reaction and presents problems in obtaining the desired concentration of desired oxide(s) in the deposited layer. Another advantage of using organometallic sources is the ease of delivering materials to a conversion site, such as a

25   burner, and the added safety that the elimination of chlorine provides.

A soot layer is deposited using improved flame hydrolysis deposition (FHD) techniques of the present invention. FHD is capable of depositing thin, uniform oxide soot or pre-sintered glass layers on planar substrates. In one embodiment, waveguiding layers are made using planar substrates made from fused silica, 100 mm in diameter, 1

30   mm thick. Waveguiding soot glass core compositions within the GeO_2-B_2O_3-P_2O_5-SiO_2 system are made and cladded with a glass cladding layer within the B_2O_3-P_2O_5-SiO_2

ternary system. The glass compositions are chosen to yield targeted refractive indices. (For example, increasing GeO_2 increases the %Δ.)

The FHD system of the present invention consists of a mixture of fuel gases and organometallic vapors that are blended and fed into a common stream within a flame

5   which comprises a conversion site that is aimed directly at the fused silica planar target substrate. Within the methane/oxygen flame, the organometallic vapors (from at least two materials selected from octamethylcyclotetrasiloxane, trimethylphosphate, triethylborate, titanium isopropoxide and germanium ethoxide) are combusted to yield multicomponent oxide soot particles.

10   The velocity of the flame, the ratios of the component gases in the flame, and the rate of vapor delivery control the final soot particle size and the degree to which they are sintered. The height of the target can be changed and the target can be traversed and/or rotated to control the temperature and distribution of the deposited particles.

Once the soot layer is deposited to the desired thickness, the sample may be

15   given a heat treatment in order to sinter and fully densify the glass. The sintering or consolidation depends on the glass composition and thickness. The thickness of the resulting waveguiding layer is typically 5-9 μm thick. The range of consolidation temperatures is from about 1150-1340°C and the hold time in this temperature range is between about 1-7 hours.

20   To make an integrated optical waveguide device, a soot layer is deposited and sintered on a planar substrate as described above to form a core layer. A waveguide circuit is etched into this core layer using photolithographic and reactive ion etching (RIE) techniques. A cladding layer is then deposited over the etched layer and sintered.

25   <u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

For a fuller understanding of the nature and objects of the invention, reference should be made to the following detailed description of a preferred mode of practicing the invention, read in connection with the accompanying drawings, in which:

30   FIG. 1 is a schematic diagram of the flame hydrolysis system for the present invention.

FIG. 2 is an enlarged perspective view of the burner, showing the flame front and tails, and how the burner-to-sample height is measured.

FIG. 3 is an exploded perspective view of the burner assembly.

FIG. 3a is a cross-sectional view through the center of the burner shown in FIG. 3.

FIG. 4 is a side sectional view of one bubbler assembly.

FIG. 5 is a plan view of the substrate holder vacuum chuck assembly.

FIG. 5a is a bottom view of the chuck bottom.

FIG. 6 is an exploded perspective view of a second embodiment of a burner assembly.

FIG. 7 illustrates a plot of consolidated glass roughness as a function of burner to sample height and the number of burner rows.

FIG. 8 illustrates a plot of change in composition as a function of sample to burner height.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is best illustrated by FIG. 1 which is a schematic diagram of the flame hydrolysis system 10 of the present invention which is suitable for use in producing oxide soot layers on planar surfaces for use in lightwave optical circuit (LOC) applications and for making integrated optical waveguide devices such as integrated optical circuits. Selected organometallic liquids are stored in bubblers 12, 14, 16, and 18, respectively. The organometallic vapors generated by the system are carried by a nitrogen source 20 which passes N_2 through heated pipes 22 into each bubbler. The organometallic liquid is vaporized within the bubbler and carried by the nitrogen vapor through heated lines 24, 26, 28 and 30, respectively. The organometallic vapors are mixed with a preselected mixture of fuel gases which include air 32, nitrogen 34, oxygen 36 and methane 38, and delivered from pipe 39 through pipe 40 to a burner assembly 42 as a single stream. Oxide soot 50 is generated by combustion of the vapors in conversion site flame 48 (see Fig. 2). The soot is deposited on a substrate 53 that is held in place by a vacuum chuck assembly 60 (Figs. 5 and 5a). Optionally, the chuck

can be traversed and/or rotated by a conventional transverse planetary mechanism 70 well known to the art. The exhaust from combustion, not shown, travels through a hood 62 to a scrubber (not shown). The burner assembly 42 and the vacuum chuck assembly 60 are surrounded by a filtered enclosure 52.

As shown in Figs. 3 and 3a, the conversion site burner assembly 42 consists of a housing 43 with a single row of 0.30" diameter holes 44. The housing contains a glass-ceramic insert 45 which contains parallel rows of holes 41, and fine mesh stainless steel screen wrap 46 that is inserted into a cylindrical manifolding chamber 47. In a preferred embodiment, which provides for a more even distribution of the vapor mixture, insert 84 of Fig. 6 replaces screen wrap 46. The fuel gas-organometallic vapor mixture enters the burner through pipe 48 which is threaded into housing 43 and which is connected to pipe 40. The manifold chamber is sealed with threaded nut 49.

A second embodiment of a burner assembly which provides for maintaining the flame points at equal height across the entire burner face is illustrated in Fig. 6. In this embodiment, the burner assembly 70 consists of a housing 72 and a burner slot 74. The burner baffle consists of two inserts that are placed inside cylindrical manifolding chamber 76. A ceramic insert 80 has two parallel rows of holes 82. A stainless steel insert 84 is constructed in such a manner that when butted against the ceramic insert provides a path for the vapors to be distributed evenly, while maintaining the flame points at equal height across the entire burner face. The vapor mixture enters the burner through pipe 86 and the chamber is sealed with threaded nut 78.

In order to ensure a layer of uniform thickness, and avoid rastering, the length "L" of the burner face or top surface which contains the burner slot or holes should be at least equal to or longer than the diameter or width of the planar substrate being coated.

The vacuum chuck assembly 60 which holds the substrate in place is shown more clearly in Figs. 5 and 5a. The chuck contains a vertical shaft 61, a rotation collar 62, an inner shielding ring 63 and an outer ring 67. The chuck bottom face 64 (Fig. 5a) shows the placement of the vacuum holes 65 that hold the sample 53 in place.

In operation, organometallic liquid components such as octamethylcyclotetrasiloxane, trimethylphosphate, triethylborate, and germanium ethoxide are separately placed in bubblers 12, 14, 16 and 18, respectively. The bubblers

are connected to a nitrogen carrier gas inlet valve with an aerator in its base and a vapor output valve for each bubbler. As more clearly shown in FIG. 4, which is an enlarged view of an individual bubbler as shown in FIG. 1, each bubbler chamber 12 is made of stainless steel and is roughly cylindrical with a round bottom and top. The bubbler contains ports for the inlet of nitrogen and out-flowing vapor output 13 to the burner 42. The nitrogen flows into the bubbler through input 15 at a given rate and delivered by an aerator tube that is submerged in the liquid and positioned at the bottom of the bubbler. For temperature control, the bubblers may optionally be wrapped in heat tape which are controlled by temperature controllers. The bubblers are then insulated with an appropriate insulator. The outlet lines are also heated by wrapped heat-tape to temperatures in excess of the boiling point of the organometallics in order to ensure that the vapor remains gaseous. All of the outlet lines lead to a single common pipe 40 which acts to mix the vapors before reaching the burner. The temperature of the pipe must be at least as high as the highest boiling point of the components.

Thermocouples may be used to monitor the temperature of the organometallic liquids. Thermocouples 17 and 18 are placed inside of each bubbler so that they are submerged in the liquid. An additional thermocouple 19 is attached to the outside of each of the bubblers, along the inlet and outlet pipes.

The bubblers also have ports for filling and draining. A drain 21 is contained in the bottom of each bubbler which is capped off unless the bubbler is being drained.

The delivery rates of the vapor and gases are governed by mass flow controllers (mfcs) 23 available under the trade name TYLAN and provide a volumetric flow rate. The organometallics in vapor form are delivered by the nitrogen stream. The methane and oxygen gases are delivered separately. The system also has the capability for nitrogen, air and hydrogen as part of the fuel premix. For one embodiment of the invention, the ranges of the mfcs are as follows:

CH_4 and O_2 = 10 sLpm (standard liter per minute)
N_2 for premix = 10 sLpm
OMCTS N_2 = 100 sccm (standard cc per minute)
TMP N_2 = 200 sccm
TEB N_2 = 50 sccm
GeE = 1000 sccm

Secondary regulator (going to the mfcs):

$$N_2 = 15 \text{ psi}$$
$$O_2 = 17 \text{ psi}$$

Only the nitrogen line is filtered to trap moisture.

The lines from the mfcs are stainless steel, and lead either to the burner manifold directly, or to the bubblers. The lines are preheated and temperature controlled by heat-tape and commercially available temperature controllers. The temperature of each line is equal to its own bubbler temperature.

Alternatively, the bubblers may be replaced with a vaporizer system which are known to the art, as shown in U.S. Patent No. 4,529,427 and JP 60-108338 and which are incorporated herein by reference.

In one embodiment of the present invention, a soot core and a soot clad layer are formed as follows:

The core soot glass composition #5 (see Table 3 is within the GeO_2-B_2O_3-P_2O_5-SiO_2 system (15.79, 3.86, 2.19, and 78.16% by weight) and the clad layer glass #10 (see Table 1) has a composition within the B_2O_3-P_2O_5-SiO_2 ternary (7.95, 3.25, and 88.8% by weight). The compositions were analyzed by standard electron probe microanalysis (EPMA) techniques.

A soot layer is deposited using standard flame hydrolysis deposition (FHD) techniques as described for Figs. 1-5. The FHD system basically consists of fuel gases and organometallic vapors that are blended and fed into a common stream within a conversion site flame that is aimed directly at a planar target substrate. Within the methane/oxygen flame, the organometallic vapors (from octamethylcyclotetrasiloxane OMCTS, trimethylphosphate TMP, triethylborate TEB, and germanium ethoxide TEOG or GE) are combusted and converted into multicomponent oxide soot particles. The delivery system uses bubblers, one for each component. The bubblers are 100-400 mL in volume and the liquid is kept at a constant level. The carrier gas is nitrogen, and the lines into the bubblers are preheated to the same temperature as the bubbler in order to avoid cooling the liquid as the N_2 flows. The temperatures for the bubblers were chosen to be as low as possible while still high enough to produce adequate vapor for a given N_2 flow. The outlet lines need to exceed the boiling point in order to keep the vapors of

the liquids from condensing. The temperature controllers for the carrier gas inlet lines, bubblers, and outlet lines are preheated to the following temperatures:

Temperature (°C)

81	Inlet to the OMCTS bubbler and the bubbler itself (22 + 18)
70	Inlet to TMP and TMP bubbler (22 + 16)
60	Inlet to TEB and TEB bubbler (22 + 14)
51	Inlet to GE and GE bubbler (22 + 12)
>176	Outlet line from OMCTS bubbler (30)
>197	Outlet line from TMP bubbler (28)
>117	Outlet line from TEB bubbler (26)
>185	Outlet line from GE bubbler (24)
>197	Common port below the burner

A fused silica substrate (100 mm diameter, 1 mm thick) is cleaned and weighed before placing on the chuck 60 which holds the sample above the flame by vacuum. The mass flow controllers are turned on to flow the carrier gas into the bubblers to deliver a given volume flow rate of vapor (sccm), as well as to control the flow rate of the methane and oxygen (sLpm). The delivery rates for the materials for the core and clad glass are as follows:

	OMCTS	TMP	TEB	GE	CH_4	O_2
core #5	0.023	0.0002	0.009	0.006	5.85	5.6
clad #10	0.025	0.0040	0.007	0	5.85	5.6

The magnehelic below the burner monitors the backpressure, usually at 1.0 in. H_2O. The height of the substrate above the flame is set accordingly to a predetermined distance and the substrate is traversed at a constant speed and simultaneously rotated by mechanism 70 to control the temperature and distribution of the deposited particles. The thickness of the glass soot is controlled by how many times the substrate traverses above the flame. Typically, the thickness of the core layer is from about 5 to 7 microns and the thickness of the clad layer is from about 4 to 20 microns.

Once the soot layer is deposited to the desired thickness, the sample is given a heat treatment in order to sinter and fully densify the glass. The consolidation schedule depends on the glass composition and thickness. The thickness of the core layer #5 is 5 μm thick; the clad layer #10 is about 4 μm thick. The top consolidation temperature for

the core was 1290° C, and for the clad was 1200° C. The hold times at those temperatures were 2 and 1 hours, respectively.

The step of forming an integrated optical waveguide circuit device includes:

1.   A device circuitry is etched into the core layer using photolithographic and reactive ion etching (RIE) techniques.

2.   A cladding layer is deposited and sintered, blanketing this device circuitry.

3.   The device is pigtailed, packaged, and connectorized.

Tables 1 and 2 show a comparison of standard deviations of oxide weight percentages from cross-section EPMA data for organometallic-generated glasses of this invention and for traditionally deposited halide-generated cladding glasses. (The lowest values for the halide-generated glasses (0.47 for SiO_2, 0.39 for B_2O_3, and 0.13 P_2O_5) were used as upper values for the degree of compositional control needed for the organometallic-generated glasses of this invention.) The glasses of this invention show significantly less variation for each oxide throughout the deposited glass layer.

Table 1 - Organometallic Clad			
Example #	P_2O_5 stdev	B_2O_3 stdev	SiO_2 stdev
1	.09	0.23	0.21
2	0.10	0.19	0.23
3	0.13	0.19	0.28
4	0.11	0.13	0.16
5	0.03	0.28	0.21
6	0.04	0.22	0.16
7	0.04	0.18	0.12
8	0.03	0.23	0.05
9	0.05	0.15	0.37
10	0.06	0.13	0.02
11	0.06	0.13	0.09
12	0.06	0.21	0.41
13	0.09	0.13	0.10
14	0.08	0.26	0.10
15	0.11	0.31	0.02
stdev max	0.13	0.31	0.41
stdev min	0.03	0.13	0.02

Table 2 - Halide Clad			
Example #	P_2O_5 stdev	B_2O_3 stdev	SiO_2 stdev
1	0.16	1.50	1.44
2	0.13	0.56	0.51
3	0.41	0.96	0.77
4	0.67	1.38	1.11
5	0.22	0.61	0.47
6	0.13	0.64	0.83
7	0.15	0.55	0.51
8	0.21	0.72	0.74
stdev max	0.67	1.50	1.44
stdev min	0.13	0.55	0.47

The following Tables 3 and 4 show comparisons of standard deviations of oxide weight percentages for cross-section EPMA data for halide-generated core-type glasses and for organometallic-generated glasses of this invention. The glasses of this invention show significantly less variation for GeO_2 and SiO_2 throughout the deposited core glass layer.

Table 3 - Organometallic Core				
Example #	P_2O_5 stdev	B_2O_3 stdev	SiO_2 stdev	GeO_2 stdev
1	0.22	0.19	0.66	0.30
2	0.02	0.16	0.59	0.45
3	0.28	0.13	0.42	0.65
4	0.21	0.24	0.17	0.26
5	0.21	0.13	0.21	0.16
6	0.19	0.13	0.20	0.28
7	0.15	0.23	0.55	0.56
8	0.13	0.20	0.05	0.08
9	0.36	0.20	0.31	0.30
10	0.14	0.12	0.01	0.21
11	0.15	0.10	0.24	0.40
stdev max	0.36	0.24	0.66	0.65
stdev min	0.02	0.01	0.01	0.08

12

Table 4 - Halide Core				
Example #	P_2O_5 stdev	B_2O_3 stdev	SiO_2 stdev	GeO_2 stdev
1	0.21	0.70	0.98	0.79
2	0.17	0.49	1.17	1.12
3	0.41	0.73	2.39	2.25
4	0.15	0.27	1.78	1.46
5	0.26	0.29	1.09	1.13
6	0.29	0.34	1.05	0.72
7	0.10	0.26	0.96	0.66
8	0.16	0.44	2.13	1.55
9	0.12	0.18	1.74	1.45
stdev max	0.41	0.73	2.39	2.25
stdev min	0.10	0.18	0.96	0.66

The following formulas illustrate the combustion products of typical organometallics which may be used in the present invention.
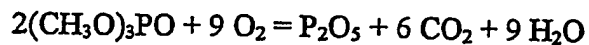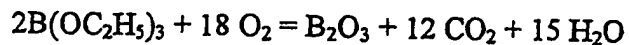
5

Table 5

Combustion Products of Organometallics
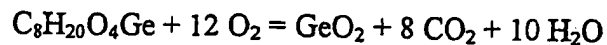
OMCTS: Octamethylcylcotetrasiloxane
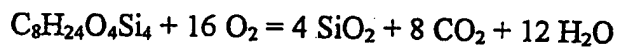
$C_8H_{24}O_4Si_4 + 16\ O_2 = 4\ SiO_2 + 8\ CO_2 + 12\ H_2O$

10

TMP: Trimethylphosphate

$2(CH_3O)_3PO + 9\ O_2 = P_2O_5 + 6\ CO_2 + 9\ H_2O$

TEB: Triethylborate

15

$2B(OC_2H_5)_3 + 18\ O_2 = B_2O_3 + 12\ CO_2 + 15\ H_2O$

GeE: Germanium ethoxide

$C_8H_{20}O_4Ge + 12\ O_2 = GeO_2 + 8\ CO_2 + 10\ H_2O$

Titanium isopropoxide

$$Ti(OC_3H_7)_4 + 18\ O_2 = TiO_2 + 12\ CO_2 + 14\ H_2O$$

In a further embodiment of the present invention, the oxide soot particles can be concurrently deposited and sintered into a uniform glass layer on the planar substrate without melting or softening the substrate. This embodiment provides the advantage of eliminating a separate consolidation step, avoids wafer warpage, and provides a glass surface which is smooth with few or no defects.

The methods by which this sintering in situ can be accomplished is by raising the substrate temperature as follows:

1. increase the methane concentration (hotter flame)

2. insulate or heat the sample holder

3. lower sample height (as close as possible to burner to obtain hotter and smaller soot particles)

4. alter the composition to a lower sintering temperature (e.g., increase B_2O_3/P_2O_5)

5. use a high velocity burner (single row vs. triple row).

The first method consists of increasing the methane to oxygen ratio, while holding all other conditions constant. The level of the oxygen is high enough to result in stoichiometric reactions while the higher methane produces a hotter flame. Samples 10 cm in diameter are used, and the pre-sintered area is circular and clear glass. The boundaries of this region are measured in terms of outer diameter (cm) (see Table 6). When the CH_4/O_2 ratio increases, the diameter increases from 4.8 to 6.0 cm. When the ratio is about the same but the CH_4 is increased, the diameter increases from 6.0 to 8.8 cm.

Table 6				
Sample #	O_2 (sLpm)	CH_4 (sLpm)	CH_4/O_2	Pre-sintered diameter
95-276	5.06	5.20	1.03	6.0 cm
95-278	6.00	5.20	0.87	4.8 cm
95-279	5.60	5.90	1.05	8.8 cm

Another method is to insulate the sample holder. This is accomplished by covering the vacuum chuck with a thick layer of form-fitting fiberfrax. The pre-sintered area increased from 6.0 to 6.5 when the chuck was kept hotter through the run (see Table 7).

Table 7				
Sample #	O_2 (sLpm)	CH_4 (sLpm)	CH_4 /O_2	Pre-sintered diameter
95-276	5.06	5.20	1.03	6.0 cm : No insulation
95-277	5.06	5.20	1.03	6.5 cm : With insulation

A third method consists of bringing the substrate holder close to the flame front. The optimum burner-to-sample height is directly above the points of the flame.

A fourth method consists of modifying the composition of the glass. Fig. 8 shows a change in composition in the consolidated glass with a ratio of B_2O_3/P_2O_5 decreasing as a function of sample-to-burner height. For higher B_2O_3/P_2O_5 ratios, the soots are more easily sintered.

A fifth method consists of increasing the velocity of the flame, such as by using a single row of burner holes rather than three rows of holes. The roughness of the soot as a function of coarseness of the soot can be correlated with the number of rows of burner holes.

Consolidated samples were measured for roughness using a profilometer, averaging 3 traces at 3 different sites over a distance of 4 mm. The roughness average as a function of sample-to-burner height is shown in Fig. 7 for samples generated using a single row burner and a triple row burner. The glass surface is smoother for the single row burner and roughens for both cases with increasing height above the burner.

While the present invention has been particularly shown and described with reference to the preferred mode as illustrated in the drawing, it will be understood by one skilled in the art that various changes in detail may be effected therein without departing from the spirit and scope of the invention as defined by the claims.

WE CLAIM:

1.   A method for forming an oxide soot layer on a planar substrate which comprises the steps:

(a)   producing a halide free gas stream containing a plurality of organometallic compounds in vapor form capable of being converted to their oxide form;

(b)   passing said stream into a conversion site to form a mixture of oxide soot particles; and

(c)   positioning a planar support in a proximate said conversion site and depositing said oxide soot particles onto said support to form a coherent oxide soot layer.

2.   The method of claim 1 in which the step of producing a halide free gas stream containing a plurality of organometallic compounds in vapor form capable of being converted to their oxide form further includes mixing a gaseous fuel with said stream.

3.   The method of claim 1 in which the step of positioning a planar support proximate said converstion site further includes positioning said planar support horizontally above said conversion site.

4.   The method of claim 1 in which the organometallic compounds comprise at least two materials selected from the group consisting of octamethylcyclotetrasiloxane, trimethylphosphate, triethylborate, titanium isopropoxide and germanium ethoxide.

5.   The method of claim 1 in which the vapors of organometallic compounds are contained in an inert gas.

6.   The method of claim 5 in which the inert gas comprises nitrogen.

7.   The method of claim 2 in which the gaseous fuel comprises methane and oxygen.

8.   A method of making an optical waveguide device which comprises the steps:

(a)   producing a halide free gas stream containing a plurality of organometallic compounds in vapor form capable of being converted to their oxide form;

(b)   mixing said gas stream with a gaseous fuel mixture to form a common vapor stream;

(c)   passing said vapor stream into the flame of a burner to form a mixture of oxide soot particles wherein said burner contains an internal baffle assembly which provides for a uniform flame points;

(d)   depositing said oxide soot particles onto a support to form a coherent oxide soot layer;

(e)   consolidating said oxide soot layer into a glass layer; and

(f)   forming an optical waveguide device with said glass layer.

9.   A method of making an integrated optical waveguide upon a supporting planar substrate which comprises the steps:

(a)   producing a halide free gas stream containing a plurality of organometallic compounds in vapor form capable of being converted to their oxide form;

(b)   mixing said gas stream with a gaseous fuel mixture to form a common vapor stream;

(c)   passing said vapor stream into the flame of a burner to form a mixture of oxide soot particles;

(d)   depositing said oxide soot particles onto a support which is heated to an elevated temperature sufficient to sinter said oxide particles in situ to form a glassy layer; and

(e)   forming an integrated optical waveguide device with said glassy layer.

10.   A method of making an optical circuit which comprises the steps:

(a)   producing a halide free gas stream containing a plurality of
organometallic compounds in vapor form capable of being converted to
their oxide form;

(b)   mixing said gas stream with a gaseous fuel to form a common vapor
stream;

(c)   passing said vapor stream into the flame of a burner to form a mixture of
oxide soot particles;

(d)   depositing said oxide soot particles onto a planar support which is
suspended above the burner to form a coherent oxide soot layer; and

(e)   forming an optical circuit from said oxide soot layer.

11.   The method of claim 10 in which the planar support is traversed over the
burner flame during the deposition of the soot layer.

12.   The method of claim 11 in which the support is also rotated during the
deposition process.

13.   The method of claim 10 in which the support is moved over the burner
flame in a planetary motion during the deposition process.

14.   Apparatus for forming an oxide soot layer on a planar substrate which
comprises:

(a)   providing a piping network which includes an input pipe to a burner for
mixing a gas stream with a gaseous fuel mixture to form a common vapor
stream;

(b)   a burner which has an outer housing which includes a top upper face
which contains a burner port which is connected to said input pipe
through a common internal manifold chamber; and

(c)   a support for a planar substrate disposed above said burner, said support having means for providing horizontal movement across the face of said burner.

15.   The apparatus of claim 14 in which said support also provides for means to rotate a substrate above said burner.

16.   The apparatus of claim 14 in which the burner port comprises an elongated slot.

17.   The apparatus of claim 14 in which the burner port comprises a plurality of holes.

18.   The apparatus of claim 17 in which the holes are contained in a single row of equally spaced holes.

19.   The apparatus of claim 14 in which the burner contains a manifolding chamber and at least one internal burner baffle member which provides for uniform flow across the length of the burner face.

20.   The apparatus of claim 14 in which the burner baffle consists of two inserts which are abutted against each other to provide a path for the common vapor steam to be evenly distributed to the burner port.

21.   The apparatus of claim 14 in which the length of the burner is equal to or longer than the diameter or width of the planar substrate.

22.   Apparatus for forming an oxide soot layer on a planar substrate which comprises:

(a)   providing a piping network which includes an input pipe to a burner for mixing a gas stream with a gaseous fuel mixture to form a common vapor stream;

(b)   a burner which has an outer housing which includes a top face which contains at least one burner port which is connected to said input pipe through a common internal manifold chamber, said manifold chamber containing a baffle member which provides for uniform vapor flow to the burner port; and

(c)   a support for a planar substrate disposed above said burner, said support having means for providing horizontal movement across the face of said burner.

23.   The apparatus of claim 22 in which the burner port comprises an elongated slot.

24.   The apparatus of claim 22 in which the burner port comprises a plurality of holes.
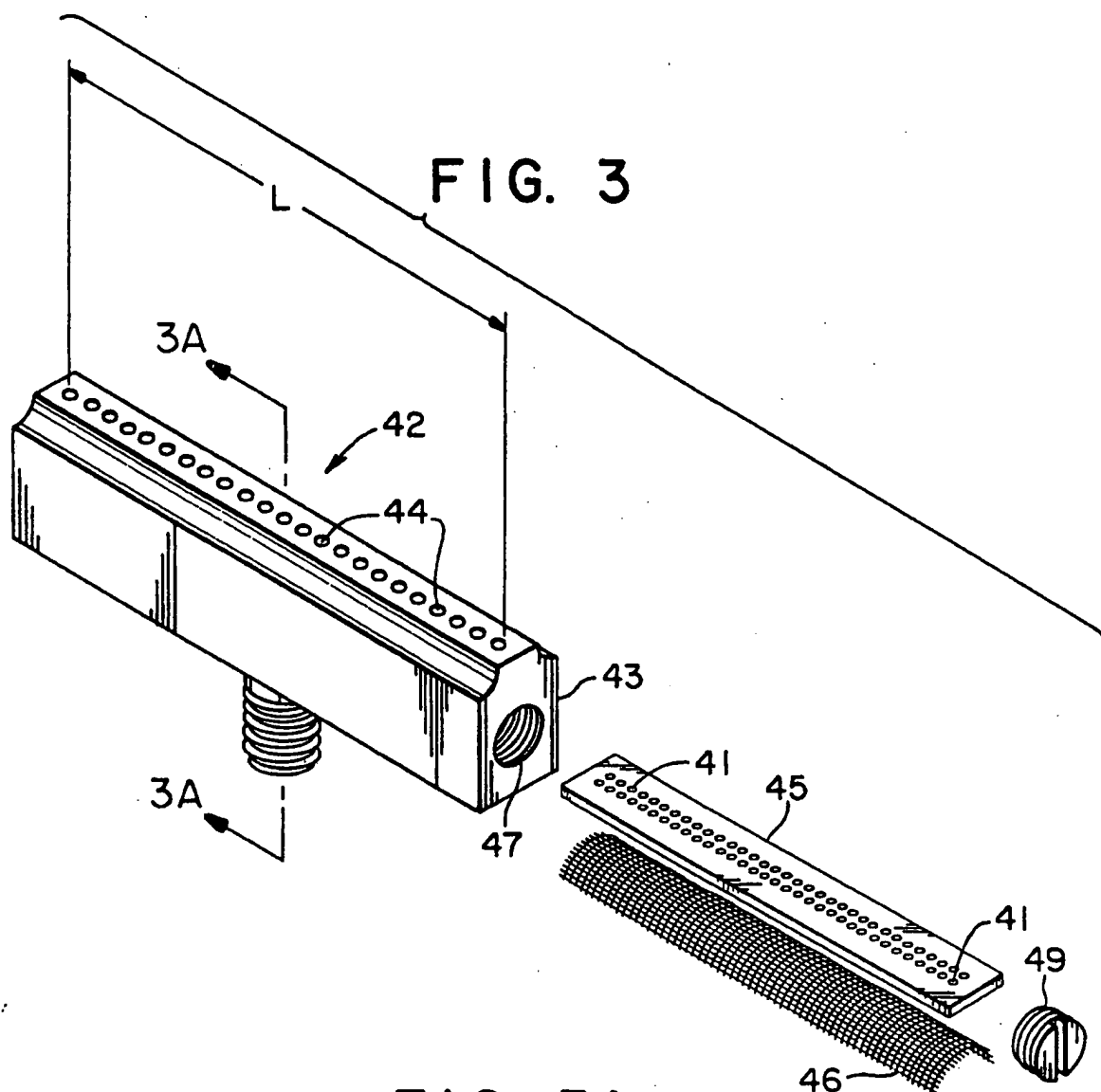
FIG. I

FIG. 2

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FIG. 4

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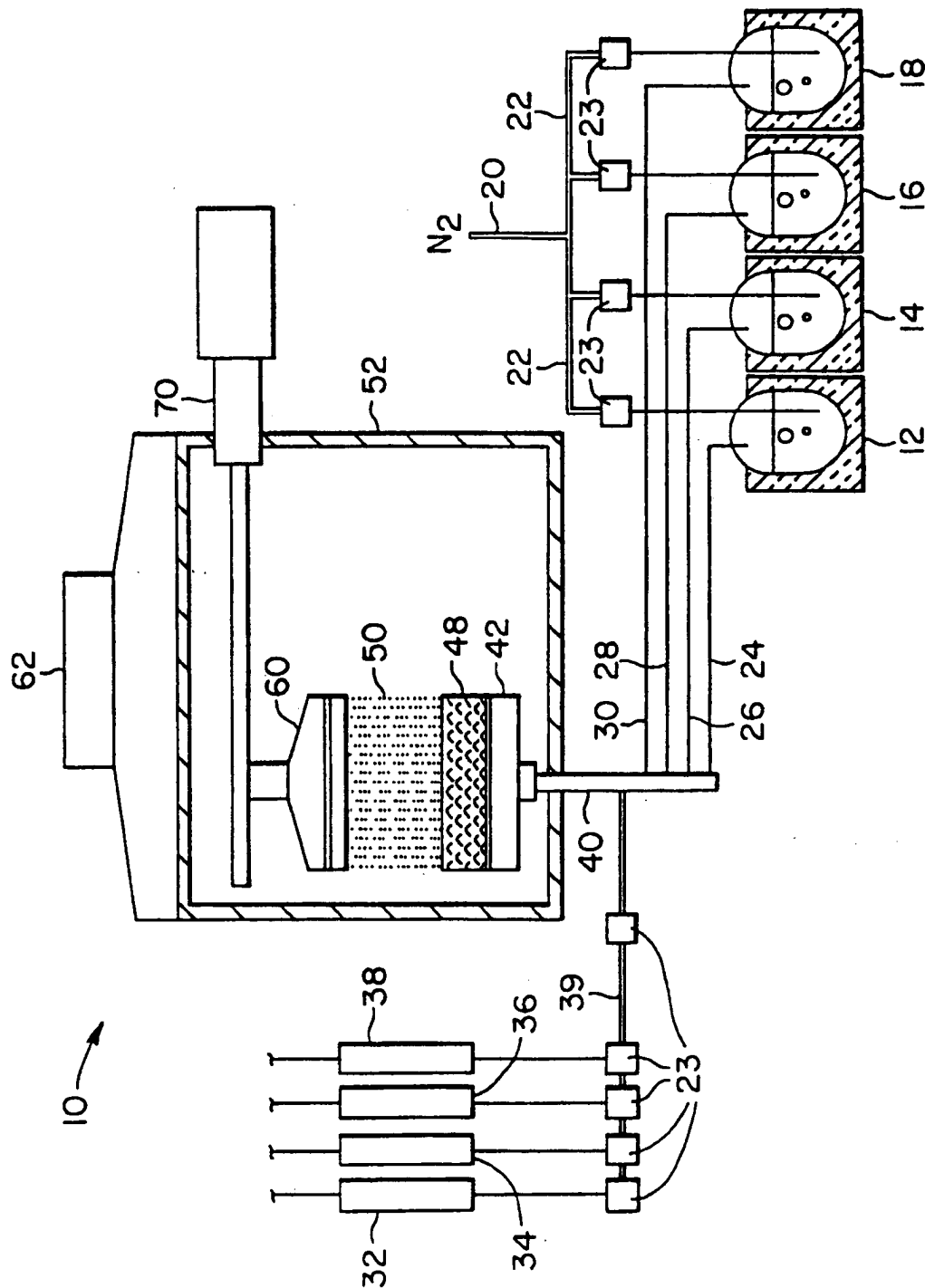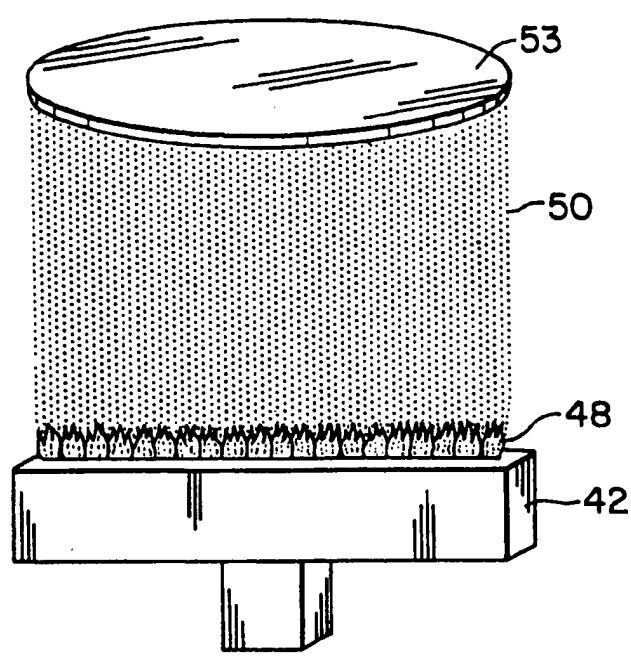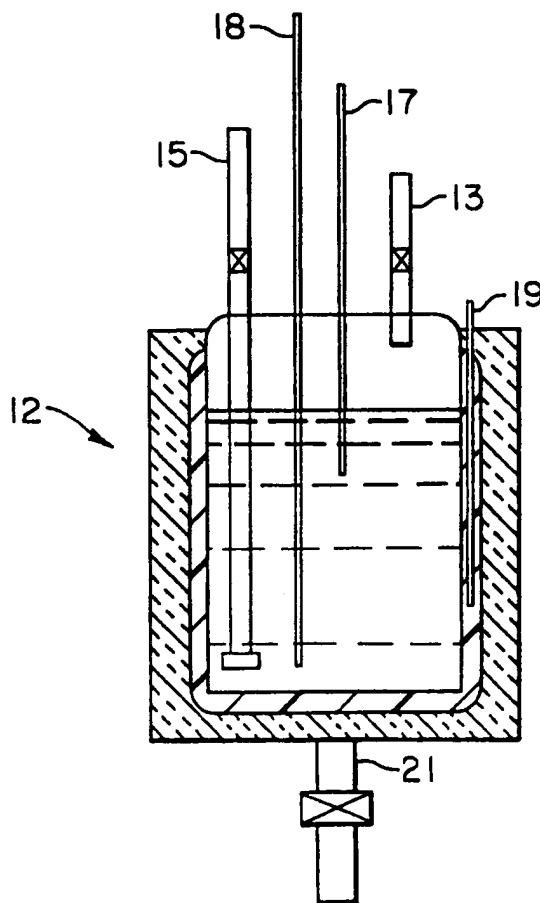
FIG. 3

FIG. 3A
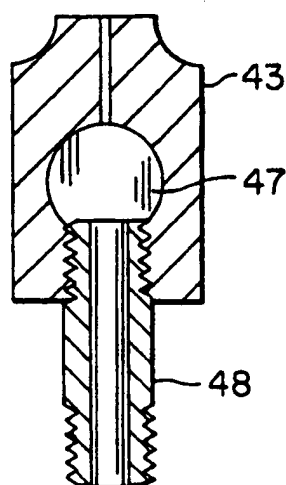
FIG. 5

FIG. 5A

F I G. 6

FIG. 7
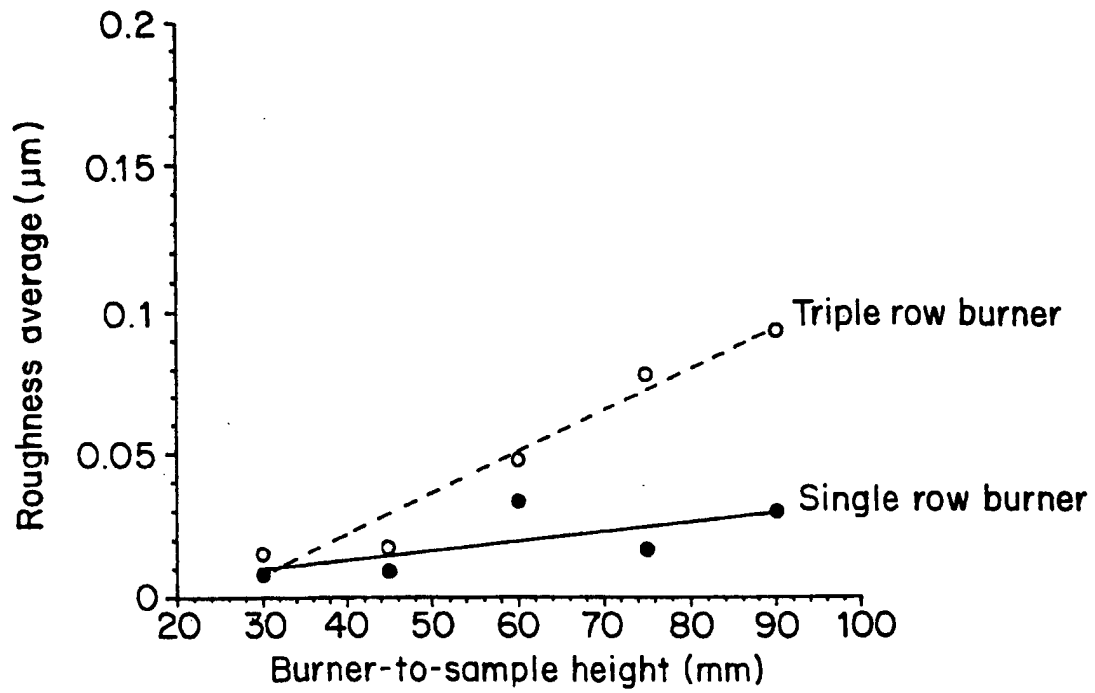
FIG. 8
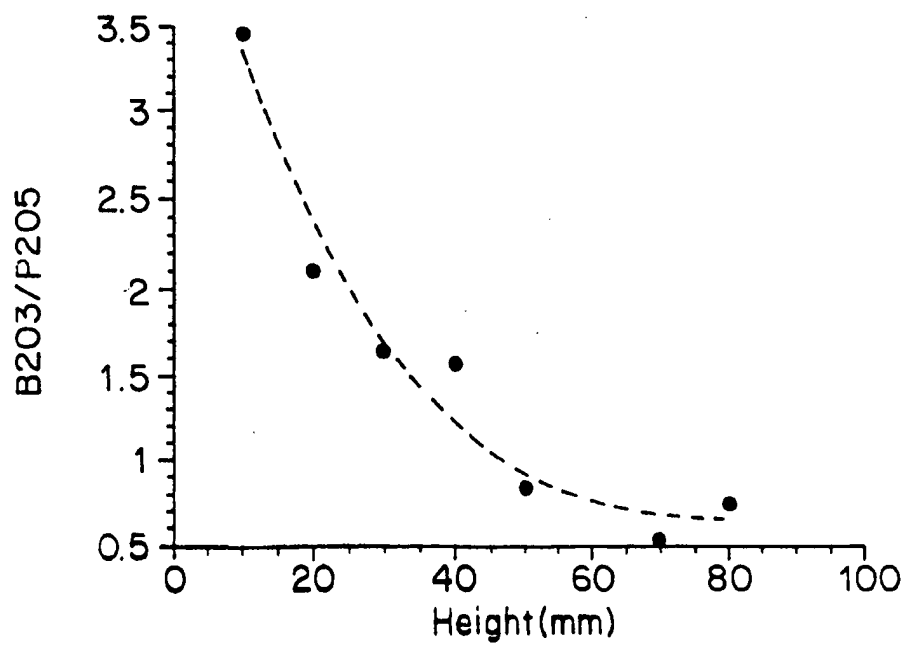
A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :C03B 19/14, 19/06
US CL :65/386, 427, 413, 17.4, 531
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 65/386, 427, 413, 17.4, 531
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 57-8506 A (EDAHIRO) 16 January 1982, English abstract.	14-15,17,21
Y		16, 18-20, 22-24
X	JP 4-74728 A (ITO) 10 March 1992, English abstract	14-15,17,21
Y		16, 18-20, 22-24
Y	JP 60-90305 A (KOBAYASHI) 21 May 1985, English abstract.	16, 23
Y	US 5,116,400 A (ABBOTT et al) 26 May 1992, figures 2-3.	18, 24
A	US 5,154,744 A (BLACKWELL et al) 13 October 1992.	

[X] Further documents are listed in the continuation of Box C.	[ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"B"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 FEBRUARY 1998	'24 FEB 1998
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Facsimile No. (703) 305-3230	Telephone No. (703) 308-0469

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,043,002 A (DOBBINS et al) 27 August 1991, entire document.	